

## **STRUCTURE FOR CONTACT FORMATION USING A SILICON-GERMANIUM ALLOY**

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10 6,075,291.

### **FIELD OF THE INVENTION**

The present invention relates generally to semiconductor integrated circuits. More particularly, it pertains to a method and structure for contact formation using  
15 doped silicon.

### **BACKGROUND OF THE INVENTION**

An insulated-gate field-effect transistor (IGFET), such as a metal-oxide semiconductor field-effect transistor (MOSFET), uses a gate to control an  
20 underlying surface channel joining a source and a drain. The channel, source and drain are located in a semiconductor substrate, with the source and drain being doped oppositely to the substrate. The gate is separated from the semiconductor substrate by an insulating layer such as a gate oxide. The operation of the IGFET involves application of an input voltage to the gate, which sets up a transverse  
25 electric field in the channel in order to modulate the longitudinal conductance of the channel.

In typical IGFET processing, the source and drain are formed by introducing dopants of second conductivity type (P or N) into a semiconductor substrate of first conductivity type (N or P) using a patterned gate as a mask. This self-aligning  
30 procedure tends to improve packing density and reduce parasitic overlap capacitances between the gate and the source and drain.

Once formed IGFETs must be wired together in order to complete functional circuits. The materials, methods, and processes of “wiring” the component parts together is generally referred to as metallization. Prior to the development of very large scale integration (VLSI)-level circuits, the primary metallization material was pure aluminum (Al). Today’s metallization processes, however, have evolved from the simple one level pure aluminum process.

Several objectives have influenced IGFET design and fabrication changes. These include; a drive for increased circuit density, an increase in the number of surface layers, and the miniaturization of individual components. The miniaturization of individual components equates to placing a greater number of IGFETs on a single chip. This in turn produces increased circuit density and yields greater functionality per chip. A further objective is to improve the performance, and particularly the speed, of the IGFET transistors. This pursuit is manifested by shorter conduction channel lengths and through efforts to obtain low contact resistivity at the IGFET junctions. These aspects offer increased IGFET speed and allow for a greater number of operations to be performed by the IGFET in less time. IGFETs are used in great quantity in computers where the push to obtain higher operation cycle speeds demands faster IGFET performance. In these efforts, it is desirable to keep costly IGFET fabrication steps to a minimum.

Contact resistance between the IGFET and different metallization layers presents a particularly difficult hurdle for further IGFET design evolution. The contact resistance is influenced by the materials, the substrate doping and the contact dimensions. The contact dimensions are typically referred to as the aspect ratio of the contact. The aspect ratio is given by the equation: Aspect Ratio = (Width of the opening)/(the Height of the opening), ( $AR=W/T$ ). The smaller the contact size or the higher the aspect ratio of the contact opening, the higher the resistance. Modern dynamic random access memory (DRAM) design often necessitates IGFETs to be formed with high aspect ratio contact openings to accommodate other components of the device. The cumulative effect of all the individual contact resistances can

dominate the conductivity of the metal system. In effect, contact resistance has become the dominant factor in ultra large scale integration (ULSI) metal system performance. Aluminum-silicon (Al-Si) contact resistance , along with its concomitant problems of electromigration and eutectic alloying have led to  
5 investigation of other contact materials for use in VLSI and ULSI metallization.

A continual need exists for creating improved junctions between the IGFET structures and subsequent metallization layers. Thus, it is desirable to uncover new material combinations and methods for processing the same which will reduce the contact resistivity between the IGFET device and subsequent metallization layers.  
10 Further, a method is desirable to achieve the above mentioned results while keeping costly fabrication steps to a minimum.

### **SUMMARY OF THE INVENTION**

A method for forming a contact using doped silicon is provided. The  
15 method includes forming a contact opening in a surface layer on a silicon substrate. Then, a first contact material is deposited on and within the contact opening. A barrier metal is deposited on the first contact material. The method further includes annealing the contact and then depositing a second contact material on the barrier metal. In one embodiment, the first contact material is germanium (Ge) which is  
20 deposited to form an alloy with the silicon substrate.

In another embodiment, a device is provided which includes a contact formed of doped silicon. The device includes a contact opening within a surface layer on a silicon substrate. A first contact material is formed on and within the contact opening. The first contact material forms an alloy with the silicon substrate.  
25 A barrier metal couples to the first contact material. And, a second contact material couples to the barrier metal. The first contact material comprises germanium (Ge).

In another embodiment, an information handling system is provided. The information handling system includes; a central processing unit, a random access memory, and a system bus which communicatively couples the central processing

unit to the random access memory. The information handling system further includes a contact formed of doped silicon. The contact has a contact opening within a surface layer on a silicon substrate. A first contact material is formed on and within the contact opening and the first contact material forms an alloy with the silicon substrate. A barrier metal couples to the first contact material. A second contact material coupling to the barrier metal.

In an alternative embodiment, a method for forming a contact is provided. The method includes forming a high aspect ratio contact opening in a surface layer on a silicon substrate. the surface layer is borophosphorus silicate glass (BPSG). An alloy material is deposited on and within the contact opening to reduce the aspect ratio of the contact opening. The method includes depositing an alloy of silicon-germanium (Si-Ge). Next, a barrier metal is deposited on the alloy material. And, finally a further contact material is deposited on the barrier metal.

In another embodiment, a device is provided, the device having a high aspect ratio contact opening within a surface layer on a silicon substrate. The device further includes, an alloy material formed on and within the contact opening to reduce the aspect ratio of the contact opening. There is a barrier metal coupling to the alloy material. And, a contact material couples to the barrier metal.

An alternative embodiment provides for an integrated circuit which has a central processing unit, a random access memory, a system bus which communicatively couples the central processing unit and the random access memory, and the device just previously recited.

Another embodiment, provides a method for forming a contact including forming a high aspect ratio contact opening in a surface layer on a silicon substrate, forming an oxide layer on and within the contact opening in the surface layer, and depositing an alloy material on the oxide layer and within the contact opening to reduce the aspect ratio of the contact opening.

In an alternative embodiment, a device is provided having a contact opening in a surface layer on a silicon substrate, an oxide layer on and within the contact

opening in the surface layer; and an alloy material on the oxide layer and within the contact opening such that the aspect ratio of the contact opening is reduced.

Another embodiment, provides a method for forming a contact including forming a contact opening in a surface layer on a silicon substrate, forming an oxide  
5 layer on and within the contact opening in the surface layer, and depositing a germanium (Ge) contact within the contact opening in the silicon substrate and annealing to form an alloy with the substrate.

In an alternative embodiment, a device is provided having a contact opening in a surface layer on a silicon substrate, an oxide layer on and within the contact  
10 opening in the surface layer; and a germanium (Ge) contact formed within the contact opening in the silicon substrate. The germanium (Ge) contact forms an alloy with the silicon substrate.

Thus various embodiments are provided for fabricating a contact which result in multiple new structures. The structures are integrated into several higher  
15 level embodiments. The improved contact has low contact resistivity. Improved junctions are thus provided between an IGFET device and subsequent metallization layers. The improvements are obtained through various steps and structures laid forth in the detailed description. The above advantages are incorporated with relatively few process steps.

20 These and other embodiments, aspects, advantages, and features of the present invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art by reference to the following description of the invention and referenced drawings or by practice of the invention. The aspects, advantages, and features of the invention are realized and attained by  
25 means of the instrumentalities, procedures, and combinations particularly pointed out in the appended claims.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

The following detailed description of the preferred embodiments can best be understood when read in conjunction with the following drawings, in which:

Figure 1A, 1B and 1C show a cross-sectional view of process steps for  
5 making a contact formation using doped silicon in accordance with an embodiment of the invention.

Figure 2 illustrates the completed contact structure in accordance with an embodiment of the invention.

Figure 3 is a block diagram of an information handling system to  
10 incorporate an embodiment of the invention.

Figure 4A, 4B and 4C show a cross-sectional view of process steps for making a contact formation using doped silicon in accordance with another embodiment of the invention.

Figure 5 illustrates the completed contact structure in accordance with  
15 another embodiment of the invention.

Figure 6 is a block diagram of an integrated circuit to incorporate an embodiment of the invention.

Figure 7A and 7B shows a cross-sectional view of process steps for making a contact formation using doped silicon in accordance with another embodiment of  
20 the invention.

Figure 8 illustrates the completed contact structure in accordance with another embodiment of the invention.

Figure 9A and 9B shows a cross-sectional view of process steps for making a contact formation using doped silicon in accordance with another embodiment of  
25 the invention.

Figure 10 illustrates the completed contact structure in accordance with another embodiment of the invention.

## **DESCRIPTION OF THE EMBODIMENTS**

In the following detailed description of the preferred embodiments, reference is made to the accompanying drawings which form a part hereof, and in which are shown by way of illustration specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

### **Method of Fabrication**

Figure 1A-1C illustrate generally the various processing techniques of one embodiment of a contact formation using doped silicon.

Figure 1A illustrates the structure at the point where transistor fabrication has been completed up through covering source/drain regions with an insulator surface layer. This stage in the fabrication may be reached in a number of well known steps which do not comprise the thrust of the present invention. These processing steps are not repeated herein.

In Figure 1A a surface layer 104 is shown on a substrate 102. The substrate 102 is an epitaxial layer suitable for integrated circuit manufacture. In one embodiment the substrate 102 is a P-type substrate with a boron background concentration on the order of  $1 \times 10^{16}$  atoms/cm<sup>3</sup>, a <100> orientation and a resistivity of 12 ohm-cm. The epitaxial surface layer of the substrate 102 is disposed on a P + base layer (not shown) and includes a planar top surface. In an alternative embodiment, the substrate 102 is an N-type substrate on an N+ base layer. The surface layer 104 is an isolation layer and can be formed of any suitable dielectric material. In one embodiment, surface layer 104 is silicon-dioxide (SiO<sub>2</sub>). In another embodiment, the surface layer 104 is formed of silicon nitride (Si<sub>3</sub>N<sub>4</sub>). A photoresist (not shown) is applied to the surface layer and selectively exposed to reveal the region where a contact is to be formed. The surface layer 104 is then removed from this region forming a contact opening 105. In one embodiment, the

contact opening 105 is formed over a source/drain region of an IGFET. The surface layer 104 is removed by any suitable etching technique. In one embodiment, the surface layer 104 is removed using a wet etch process, such as a buffered oxide etch (BOE). In an alternative embodiment, the surface layer 104 is removed using a dry etch process, such as reactive ion etching (RIE). Next, a first contact material 106 is deposited on and within the contact opening 105. The first contact material 106 is deposited by an ion implantation method. In one embodiment, first contact material 106 is germanium (Ge).

Next, the photoresist is stripped using conventional photoresist stripping techniques. A barrier metal 110 is deposited on the first contact material 106. The barrier metal is deposited using any suitable technique, such as by chemical vapor deposition (CVD). In one embodiment, the barrier metal 110 is a titanium-nitride (TiN)/titanium (Ti) layer. A layer of titanium (Ti) 110A is deposited beneath the titanium-nitride (TiN) layer 110B to provide a high-conductivity intermediate layer with the silicon substrate 102. In an alternate embodiment, the titanium (Ti) layer 110A is deposited prior to depositing the first contact material 106. Then, in a subsequent step the first contact material 106 is deposited into the substrate 102 by ion implantation. The structure is now as appears in Figure 1A.

Figure 1B illustrates the structure following the next sequence of process steps. A high temperature rapid thermal anneal (RTA) is performed. As those skilled in the art will appreciate, this process cures out the crystal damage induced by the previous ion implantation process. Additionally, the annealing process forms an alloy 108 between the first contact material 106 and the silicon substrate 102. A second contact material 112 is deposited on the barrier metal 110. The second contact material 112 is deposited by any suitable method, such as by low pressure chemical vapor deposition (LPCVD). In one embodiment, the second contact material 112 is a refractory metal. In an alternate embodiment, the second contact material 112 is any material which possesses a sufficiently low contact resistivity. The structure is now as appears in Figure 1B.



Figure 1C illustrates the structure following the final sequence of process steps. A third contact material 114 is deposited on the second contact material 112. The third contact material is deposited by any suitable technique, such as by chemical vapor deposition (CVD). In one embodiment, the third contact material is aluminum (Al). The final structure is as shown in Figure 1C. Additional metallization layers and accompanying contact formation, not included here, are achieved using conventional techniques. These further processing steps are not repeated herein. Likewise, the principal processing steps disclosed herein may be combined with other steps apparent to those skilled in the art.

The present invention includes numerous variations to the embodiment described above. For instance, the completed device illustrated in Figure 2 is one embodiment of the invention formed on a top surface of a semiconductor substrate 202. Figure 2 is a cross sectional view wherein a surface layer 204 is shown on a silicon substrate 202 and a contact opening 205 is formed within the surface layer 204 on the substrate 202. The surface layer 204 is an isolation layer and can be formed of any suitable dielectric material. In one embodiment, surface layer 204 is silicon-dioxide ( $\text{SiO}_2$ ). In another embodiment, the surface layer 204 is formed of silicon nitride ( $\text{Si}_3\text{N}_4$ ). A first contact material 208 is formed on and within the contact opening 205. The first contact material 208 is an alloy formed with the silicon substrate 202. In one embodiment, the first contact material 208 is germanium (Ge). A barrier metal 210 couples to the first contact material 208. In one embodiment, the barrier metal 210 comprises a layer of titanium (Ti) 210A topped by a layer of titanium-nitride (TiN) 210B. In one embodiment, the first contact material 208 alloy is formed prior to forming the barrier metal 210. In an alternate embodiment, the first contact material 208 is formed subsequent to forming the barrier metal 210. A second contact material 212 is couples to the barrier metal 210. In one embodiment, the second contact material 212 is a refractory metal. A third contact material 214 couples to the second contact material 212. In one embodiment, the third contact material is aluminum (Al).

Thus the invention provides a method and structure for a contact formation using doped silicon. The contact formation provides low contact resistivity. Advantageously, the invention is well-suited for use in a device such as an integrated circuit chip, as well as an electronic system including a microprocessor, a memory and a system bus. The electronic system may also be an information handling system 300 as shown in Figure 3. The information handling system includes a central processing unit (CPU) 304, a random access memory (RAM) 332, a read only memory (ROM) 334, and a system bus 330 for communicatively coupling the CPU 304, the RAM 332 and the ROM 334. The system 300 also includes an input/output bus 310 and several peripheral devices, such as 312, 314, 316, 318, 320, and 322. The device peripherals attach to the input output bus 310. Peripheral devices include hard disk drives, floppy disk drives, monitors, keyboards and other such peripherals. The information handling system 300 includes a contact formation, such as is shown in Figure 2, in the CPU 304, the RAM 332 and the ROM 334. The contact formation provides a low contact resistivity at the junctions between an IGFET device and subsequent metallization layers. The low contact resistivity provides for stronger and more reliable electronic coupling, thus facilitating better data flow throughout the information handling system.

Figure 4A-4C illustrate generally the various processing techniques of another embodiment of a contact formation using doped silicon, according to the teachings of the present invention.

In Figure 4A illustrates the structure at the point where transistor fabrication has been completed up through covering source/drain regions a insulator surface layer. This stage in the fabrication may be reached in a number of well known steps which do not comprise the thrust of the present invention. These processing steps are not repeated herein.

In Figure 4A a surface layer 404 is shown on a substrate 402. The substrate 402 is an epitaxial layer suitable for integrated circuit manufacture. In one embodiment the substrate 402 is a P-type substrate with a boron background

concentration on the order of  $1 \times 10^{16}$  atoms/cm<sup>3</sup>, a <100> orientation and a resistivity of 12 ohm-cm. The epitaxial surface layer of the substrate 402 is disposed on a P + base layer (not shown) and includes a planar top surface. In an alternative embodiment, the substrate 402 is an N-type substrate on an N+ base layer. The surface layer 404 is an isolation layer and can be formed of any suitable dielectric material. In one embodiment, surface layer 404 is borophosphorus silicate glass (BPSG). A photoresist (not shown) is applied to the surface layer 404 and selectively exposed to reveal the region where a contact is to be formed. The surface layer 404 is then removed from this region forming a high aspect ratio contact opening 405. In one embodiment, the high aspect ratio contact opening 405 is formed over a source/drain region of an IGFET. The surface layer 404 is removed by any suitable etching technique. In one embodiment, the surface layer 404 is removed using a wet etch process, such as a buffered oxide etch (BOE). In an alternative embodiment, the surface layer 404 is removed using a dry etch process, such as reactive ion etching (RIE). Next, an alloy material 406 is deposited on and within the contact opening 405 to reduce the aspect ratio of the contact opening 405. The alloy material 406 is deposited by an ion implantation method. In one embodiment, the alloy material 406 is deposited by low temperature epitaxial deposition. In one embodiment, the alloy material 406 is a silicon-germanium (Si-Ge) alloy. The structure is now as appears in Figure 4A.

Figure 4B illustrates the structure following the next sequence of process steps. The photoresist is stripped using conventional photoresist stripping techniques. A barrier metal 410 is deposited on the alloy material 406. The barrier metal 410 is deposited using any suitable technique, such as by chemical vapor deposition (CVD). In one embodiment, the barrier metal 410 is a titanium-nitride (TiN)/titanium (Ti) layer. A layer of titanium (Ti) 410A is deposited beneath the titanium-nitride (TiN) layer 410B to provide a high-conductivity intermediate layer with the alloy material 406. A first contact material 412 is deposited on the barrier metal 410. The first contact material 412 is deposited by any suitable method, such

as by low pressure chemical vapor deposition (LPCVD). In one embodiment, the first contact material 412 is a refractory metal. In an alternate embodiment, the first contact material 412 is any material which possesses a sufficiently low contact resistivity. The structure is now as appears in Figure 4B.

5           Figure 4C illustrates the structure following the final sequence of process steps. A second contact material 414 is deposited on the first contact material 412. The second contact material 414 is deposited by any suitable technique, such as by chemical vapor deposition (CVD). The final structure is as shown in Figure 4C. Additional metallization layers and accompanying contact formation, not included  
10   here, are achieved using conventional techniques. These further processing steps are not repeated herein. Likewise, the principal processing steps disclosed herein may be combined with other steps apparent to those skilled in the art.

          The present invention includes numerous variations to the embodiment described above. For instance, the completed device illustrated in Figure 5 is one  
15   embodiment of the invention formed on a top surface of a semiconductor substrate 502, according to the method taught in Figures 4A through 4C. Figure 5 is a cross sectional view wherein a surface layer 504 is shown on a silicon substrate 502 and a high aspect ratio contact opening 505 is formed within the surface layer 504 on the substrate 502. The surface layer 504 is an isolation layer and can be formed of  
20   any suitable dielectric material. In one embodiment, surface layer 504 is borophosphorus silicate glass (BPSG). An alloy material 506 is formed on and within the contact opening 505 to reduce the aspect ratio of the contact opening 505. The alloy material 506 is formed by an ion implantation method. In one embodiment, the alloy material 506 is formed by low temperature epitaxial  
25   deposition. In one embodiment, the alloy material 506 is formed of silicon-germanium (Si-Ge). A barrier metal 510 couples to the alloy material 506. In one embodiment, the barrier metal 510 comprises a layer of titanium (Ti) 510A topped by a layer of titanium-nitride (TiN) 510B. A first contact material 512 couples to the barrier metal 510. A second contact material 514 couples to the first contact

material 512.

Thus the invention provides a method and structure for a contact formation using doped silicon. The contact formation provides low contact resistivity. Advantageously, the invention is well-suited for use in a device such as an integrated circuit chip, as well as an electronic system including a microprocessor, a memory and a system bus. The electronic system may also include an integrated circuit 600 as shown in Figure 6. The information handling system includes a central processing unit (CPU) 604, a random access memory (RAM) 632, a read only memory (ROM) 634, and a system bus 630 for communicatively coupling the CPU 604, the RAM 632 and the ROM 634. The system 600 also includes an input/output bus 610 and several devices peripheral devices, such as 612, 614, 616, 618, 620, and 622. The device peripherals attach to the input output bus 610. Peripheral devices include hard disk drives, floppy disk drives, monitors, keyboards and other such peripherals. The information handling system 600 includes a contact formation, such as is shown in Figure 5, in the CPU 604, the RAM 632 and the ROM 634. The contact formation provides a low contact resistivity at the junctions between an IGFET device and subsequent metallization layers. The low contact resistivity provides for stronger and more reliable electronic coupling, thus facilitating better data flow throughout the integrated circuit.

Figure 7A-7B illustrate generally the various processing techniques of another embodiment of a contact formation using doped silicon.

Figure 7A illustrates the structure at the point where transistor fabrication has been completed up through covering source/drain regions with an insulator surface layer. This stage in the fabrication may be reached in a number of well known steps which do not comprise the thrust of the present invention. These processing steps are not repeated herein.

In Figure 7A a surface layer 704 is shown on a substrate 702. The substrate 702 is an epitaxial layer suitable for integrated circuit manufacture. In one embodiment the substrate 702 is a P-type substrate with a boron background

concentration on the order of  $1 \times 10^{16}$  atoms/cm<sup>3</sup>, a <100> orientation and a resistivity of 12 ohm-cm. The epitaxial surface layer of the substrate 702 is disposed on a P + base layer (not shown) and includes a planar top surface. In an alternative embodiment, the substrate 702 is an N-type substrate on an N+ base layer. The surface layer 704 is an isolation layer and can be formed of any suitable dielectric material. In one embodiment, surface layer 704 is borophosphorus silicate glass (BPSG). A photoresist (not shown) is applied to the surface layer and selectively exposed to reveal the region where a contact is to be formed. The surface layer 704 is then removed from this region forming a high aspect ratio contact opening 705. In one embodiment, the contact opening 705 is formed over a source/drain region of an IGFET. The surface layer 704 is removed by any suitable etching technique. In one embodiment, the surface layer 704 is removed using a wet etch process, such as a buffered oxide etch (BOE). In an alternative embodiment, the surface layer 704 is removed using a dry etch process, such as reactive ion etching (RIE). Next, an oxide layer 708 is formed on and within the contact opening 705. The oxide layer 708 can be formed using any suitable technique, such as by thermal growth or chemical vapor deposition. In one embodiment, the oxide layer 708 is formed from tetraethyl orthosilicate (TEOS) sources and the deposition is performed by low pressure chemical vapor deposition (LPCVD). The structure is now as appears in Figure 7A.

Figure 7B illustrates the structure following the final sequence of steps. The oxide layer 708 is selectively etched back from the substrate 702 using any suitable process, such as reactive ion etching (RIE). An alloy material 706 is deposited on the oxide layer 708 and within the contact opening 705 to reduce the aspect ratio of the contact opening 705. In one embodiment, the alloy material 706 is a silicon-germanium (Si-Ge) alloy. The alloy material is deposited by an ion implantation method. In one embodiment, the alloy material is deposited by low temperature epitaxial deposition. The structure is now as appears in Figure 7B. Additional metallization layers and accompanying contact formation, not included

here, are achieved using conventional techniques. These further processing steps are not repeated herein. Likewise, the principal processing steps disclosed herein may be combined with other steps apparent to those skilled in the art.

The present invention includes numerous variations to the embodiment described above. For instance, the completed device illustrated in Figure 8 is one embodiment of the invention formed, according to the method of Figures 7A-7B on a top surface of a semiconductor substrate 802. Figure 8 is a cross sectional view wherein a surface layer 804 is shown on a silicon substrate 802 and a high aspect ratio contact opening 805 is formed within the surface layer 804 on the substrate 802. The surface layer 204 is an isolation layer and can be formed of any suitable dielectric material. In one embodiment, surface layer 804 is borophosphorus silicate glass (BPSG). An oxide layer 808 is formed on and within the contact opening 805. In one embodiment, the oxide layer 808 is formed from a tetraethyl orthosilicate (TEOS) sources and formed by low pressure chemical vapor deposition (LPCVD). An alloy material 806 is on the oxide layer 808 and within the contact opening 805. In one embodiment, the alloy material 806 is a silicon-germanium (Si-Ge) alloy.

Figure 9A-9B illustrate generally the various processing techniques of another embodiment of a contact formation using doped silicon.

Figure 9A illustrates the structure at the point where transistor fabrication has been completed up through covering source/drain regions with an insulator surface layer. This stage in the fabrication may be reached in a number of well known steps which do not comprise the thrust of the present invention. These processing steps are not repeated herein.

In Figure 9A a surface layer 904 is shown on a substrate 902. The substrate 902 is an epitaxial layer suitable for integrated circuit manufacture. In one embodiment the substrate 902 is a P-type substrate with a boron background concentration on the order of  $1 \times 10^{16}$  atoms/cm<sup>3</sup>, a <100> orientation and a resistivity of 12 ohm-cm. The epitaxial surface layer of the substrate 902 is

disposed on a P + base layer (not shown) and includes a planar top surface. In an alternative embodiment, the substrate 902 is an N-type substrate on an N+ base layer. The surface layer 904 is an isolation layer and can be formed of any suitable dielectric material. In one embodiment, surface layer 904 is borophosphorus silicate glass (BPSG). A photoresist (not shown) is applied to the surface layer and selectively exposed to reveal the region where a contact is to be formed. The surface layer 904 is then removed from this region forming a contact opening 905. In one embodiment, the contact opening 905 is formed over a source/drain region of an IGFET. The surface layer 904 is removed by any suitable etching technique.

10 In one embodiment, the surface layer 904 is removed using a wet etch process, such as a buffered oxide etch (BOE). In an alternative embodiment, the surface layer 904 is removed using a dry etch process, such as reactive ion etching (RIE). Next, an oxide layer 908 is formed on and within the contact opening 905. The oxide layer 908 can be formed using any suitable technique, such as by thermal growth or

15 chemical vapor deposition. In one embodiment, the oxide layer 908 is formed from tetraethyl orthosilicate (TEOS) sources and the deposition is performed by low pressure chemical vapor deposition (LPCVD). The structure is now as appears in Figure 9A.

Figure 9B illustrates the structure following the final sequence of steps.

20 The oxide layer 908 is selectively etched back from the substrate 902 using any suitable process, such as reactive ion etching (RIE). A germanium (Ge) contact 906 is deposited within the contact opening 906 and in the silicon substrate 902. The alloy material is deposited by an ion implantation method. Next, a high temperature rapid thermal anneal (RTA) is performed. As those skilled in the art

25 will appreciate, this process cures out the crystal damage induced by the previous ion implantation process. Additionally, the annealing process forms an alloy 907 between the germanium (Ge) 906 and the silicon substrate 902. The structure is now as appears in Figure 9B. Additional metallization layers and accompanying contact formation, not included here, are achieved using conventional techniques.



These further processing steps are not repeated herein. Likewise, the principal processing steps disclosed herein may be combined with other steps apparent to those skilled in the art.

The present invention includes numerous variations to the embodiment described above. For instance, the completed device illustrated in Figure 10 is one embodiment of the invention formed, according to the method of Figures 9A-9B on a top surface of a semiconductor substrate 1002. Figure 10 is a cross sectional view wherein a surface layer 1004 is shown on a silicon substrate 1002 and a contact opening 1005 is formed within the surface layer 1004 on the substrate 1002.

10 The surface layer 1004 is an isolation layer and can be formed of any suitable dielectric material. In one embodiment, surface layer 1004 is borophosphorus silicate glass (BPSG). An oxide layer 1008 is formed on and within the contact opening 1005. In one embodiment, the oxide layer 1008 is formed from a tetraethyl orthosilicate (TEOS) sources and formed by low pressure chemical vapor

15 deposition (LPCVD). A germanium (Ge) contact is formed within the contact opening 1005 such that the germanium contact forms an alloy 1007 with the silicon substrate 1002.

Although specific embodiments have been illustrated and described herein, it is appreciated by those of ordinary skill in the art that any arrangement which is

20 calculated to achieve the same purpose may be substituted for the specific embodiments shown. This application is intended to cover any adaptations or variations of the present invention. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.